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The effects and outcomes of electrolyte disturbances and asphyxia on newborns hearing

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ABSTRACT

Objective: To determine the effect of electrolyte disturbances (ED) and asphyxia on infant hearing and hearing outcomes.
Study design: We conducted newborn hearing screening with transient evoked otoacoustic emission (TEOAE) test on a large scale (>5000 infants). The effects of ED and asphyxia on infant hearing and hearing outcomes were evaluated.
Result: The pass rate of TEOAE test was significantly reduced in preterm infants with ED (83.1%, multiple logistic regression analysis: $P < 0.01$) but not in full-term infants with ED (93.6%, $P = 0.41$). However, there was no significant reduction in the pass rate in infants with asphyxia ($P = 0.85$). We further found that hypocalcaemia significantly reduced the pass rate of TEOAE test (86.8%, $P < 0.01$). In the follow-up recheck at 3 months of age, the pass rate remained low (44.4%, $P < 0.01$).
Conclusion: ED is a high-risk factor for preterm infant hearing. Hypocalcaemia can produce more significant impairment with a low recovery rate.

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1. Introduction

Hearing is one of the most important neural senses. Lack of auditory input in infants can arrest or disrupt normal auditory development [1–5], result in cortical reorganization [5,6], and impede language, psychosocial, emotional, and cognitive development in early childhood [7,8]. These disorders can eventually undermine later educational and vocational attainment [5,9–12].

Many factors can influence or impair infant hearing [13]. The Joint Committee on Infant Hearing (JCIH) published the risk factors for infant hearing, such as aspiration syndrome, asphyxia, hyperbilinubinemia, low birth weight, sepsis, and ototoxic medication [14]. Many authors have studied the presence of risk factors identified by the JCIH [15–17]. However, little attention is placed on these etiologic factors-associated pathophysiological dysfunctions and hearing outcomes of these pathophysiological dysfunctions.

Newborn hearing screening can detect early hearing loss and permits early identification of at-risk infants [12,13,18]. It also provides a means to evaluate the effects of risk-factors associated pathophysiologcal dysfunctions on infant hearing and hearing outcomes [19]. Currently, two methods are suggested for newborn hearing screening by the JCIH [14]: the otoacoustic emission (OAE) and the auditory brainstem response (ABR). OAEs are generated by active amplification in the cochlea, while ABR is a measure of auditory function through the level of brainstem [20]. OAE and other acoustic emission measurements can sensitively detect changes in active cochlear amplification *in vivo* [21], which is required for normal mammalian hearing. Deficiency of active cochlear amplification can induce hearing loss [22,23]. Reduction of OAE reflects active cochlear amplification impaired; ABR is also reduced [21]. However, *vice versa*, it is not correct.

Electrolyte disturbance (ED) and asphyxia are two common pathophysiological dysfunctions in infants, associated with many high-risk factors, and exist in procedures of many diseases in the clinic [24]. It has also been well-known that ionic homeostasis and oxygen supplement are critical for hair cell mechano-transduction procedure, endocochlear potential (EP) generation, and active cochlear amplification [25]. In this study, we used newborn hearing screening with transient evoked otoacoustic emission (TEOAE) recording to evaluate the effects of ED and asphyxia on infant hearing and hearing outcomes. We found that ED can produce significant impairment in infant hearing, especially in preterm infants.

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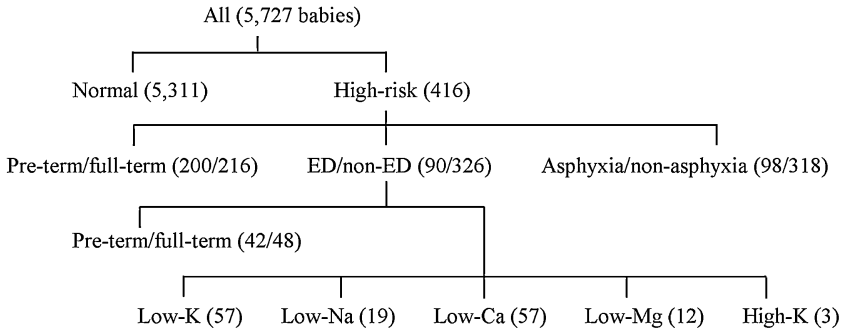

Fig. 1. A flow chart of the experimental design and data analysis.

2. Methods

2.1. Eligibility and enrollment

Infants born at Bao'an Maternal and Child Health Care Hospital, Shenzhen, PR China from January 2009 to August 2010 were enrolled in this study. As a part of the Newborn Hearing Screening Program (NHSP) in China, all newborns were offered a hearing screening. The study protocol was approved by the hospital review board. Written informed consent was obtained from the infant's parents.

2.2. Study design

Infants who had apparent history of ototoxic medication were excluded from this study. Infants who were full-term delivered without any complications were assigned to the normal group (Fig. 1). Infants who were admitted to the neonatal intensive care unit (NICU) for more than 48 h were eligible to be enrolled in the NICU group. The general medical records of infants including birth weight, gestational age, dysmorphic features, and diagnosis were collected. Preterm delivery was defined as delivery at 37 weeks of gestation or less. Hypocalcaemia was defined as less than 2.2 mM calcium level in the blood. Hypokalemia and hyperkalemia were defined as $K^+ < 3.5$ mM and $K^+ > 5.5$ mM, respectively, in the blood. Hypomagnesaemia and hyponatremia were defined as less than 1.5 mg/dL magnesium level and 135 mM sodium level, respectively, in the blood. Asphyxia was defined by the criteria suggested by the American Academy of Pediatrics (AAP) and American College of Obstetrics and Gynecology (ACOG).

2.3. Hearing screening

Transiently evoked otoacoustic emissions (TEOAE) was used for newborn hearing screening [14]. TEOAE was evoked by clicks at an intensity of 60 dB SPL by Otometrics Capella System (Madsen, Taastrup, Denmark) with a default screening test model. The first screening test was performed at 2–5 days after birth. In the NICU group, the first screening test was performed at the 38th–41st week (median: 39.6 weeks) of postconceptional age (PCA). If infants failed, the test would be repeated in 3–5 days before babies discharged from the hospital. If both tests were failed, the second follow-up test of the same TEOAE examination would be performed at 3 months of age.

2.4. Statistical analysis

The SPSS 13.0 (SPSS Inc., Chicago, IL) statistical package was used for statistical analysis. A multiple logistic regression with Hosmer–Lemeshow goodness-of-fit statistics analysis was used with "pass" and "fail" being the dependable variable. *P*-values less than 0.05 were considered statistically significant.

3. Results

3.1. TEOAE test in normal and NICU infants

A total of 5727 infants (11,454 ears) were enrolled in this study, of which 416 infants (832 ears) were admitted to the NICU (Table 1). The pass rate of TEOAE in the normal group was 99.9%. Only 6 infants (about 1:1000 ratio) in the normal group were referred in the TEOAE test. In the NICU group, the pass rate was 94.3% and is significantly lower than that in the normal infant group ($P < 0.01$).

Because it is unclear which risk factors play an independent contributing role to failure in TEOAE test, only by comparison within NICU infants the risk factors specific to test failure can be assessed. We further divided NICU infants into preterm and full-term groups according to gestational weeks (Fig. 1). Of a total of 416 infants in the NICU group, 200 were preterm infants and 216 were full-term infants. The gestational age (GTA) of enrolled infants in the preterm group was from 27.3 to 37 weeks (median: 34.6 weeks). In the full-term group, the GTA of infants was from 37.1 to 44 weeks (median: 39 weeks). Characteristics of the preterm group and the full-term group are shown in Table 2. Baseline characteristics were similar in two groups. Common dysfunctions and etiologic factors in the preterm group were ED (21%), low-birth-weight (17%), aspiration syndrome (15%), asphyxia (8%), hyperbilinubinemia (9%), and infection (14%). In the full-term infant group, common dysfunctions and etiologic factors were ED (22%), asphyxia (32%), aspiration syndrome (35%), hyperbilinubinemia (24%), and infection (16%).

The pass rates of TEOAE test in the preterm group and the full-term group were 93.2% and 95.3%, respectively (Fig. 2). There was no significant difference between them ($P = 0.23$), indicating that premature delivery alone does not affect hearing function significantly.

3.2. Pass rate of TEOAE test in infants with asphyxia and ED

Asphyxia and ED are two major physiological dysfunctions in infants (Table 2). TEOAE test shows that the passing rate had no significant reduction in infants with asphyxia (Fig. 2). The pass rates of TEOAE test in the asphyxia infants and non-asphyxia infants were 93.3% and 94.2%, respectively. There was no significant difference between them ($P = 0.85$).

Table 1
Significant reduction of pass rate of TEOAE in high-risk infants.

	1st test Pass/total (%)	Follow-up Pass/total (%)	Total Pass/total (%)
High-risk	631/832 (75.9*)	143/190 (74.6*)	774/821 (94.3*)
Normal	9582/10,622 (90.2)	500/512 (97.7)	10,082/10,094 (99.9)

* $P < 0.01$

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